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Marine Gas Hydrates: Future Energy or Environmental Killer?

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Abstract

Marine gas hydrates are regard as a new energy in the 21st century with the characteristics of high energy density, huge amount of resources and cleaning. It has important significances for resources development, environmental protection and global climate changing. This large marine gas hydrate reservoir is further suggested as an important component of the global carbon cycle and as a future energy source. But its decomposition and release can lead to decrease the stability of seabed, causing submarine landslide. And its overflowed can intensify the greenhouse effect, interaction between which can lead to more serious ecological and environmental disasters. Due to the limitations of the occurrence mode and the technical level of marine gas hydrates, at present, the development and utilization of the resources are still tentative. How to use these future energy is a challenge, it must be considered the only way to protect biodiversity and vulnerable marine ecosystems effectively.

Keywords: Marine gas hydrates; future energy; resource characteristics; environmental effects

1. Introduction

Gas hydrates are also known as natural gas hydrates, methane gas hydrates, etc., which are a solid ice-like substance formed by hydrocarbon gas molecules methane–based and water molecules. Gas hydrates are mainly distributed in the slope of the seabed sediments with the depth of 400~1000m, temperature below 10 ℃ and the pressure is greater than 3.5 Mpa, and the Arctic tundra in Russia, Canada and other countries[1]. Ocean is the main place for gas hydrates to formation and preservation. Gas hydrates, with the characteristics of high energy density, huge amount of resources and cleaning, are considered as an ideal

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alternative energy in the 21st century. It has important significances for resources development, environmental protection and global climate changing.

2. Marine Gas Hydrates: Resource Characteristics

2.1. Resource Characteristics of Marine Gas Hydrates

Methane is the dominant hydrocarbon in gas hydrates, but other higher hydrocarbon gases (ethane, propane through isopentane) may also be significant [2, 3]. The global volume of hydrate-bound gas is uncertain [4]. It appears that the global estimates of hydrate-bound gas decreased by at least one order of magnitude from 1970s~early 1980s (abourt 10^{17}~10^{18} m^3) to late 1980s~early 1990s (10^{16} m^3) to late 1990s~present (10^{14}~10^{15} m^3). The decrease of estimates is a result of growing knowledge of the distribution and concentration of gas hydrates in marine sediments and ongoing efforts to better constrain the volume of hydrate-bearing sediments and their gas yield[5]. Gornitz et al. suggests that the volume of methane is $1.8 \times 10^{16} \sim 3.4\times10^{17}$ m^3 in the global submarine gas hydrates reservoir [6]. However, estimates as high as 7600×10^{15} m^3 [7] and as low as 0.2×10^{15} m^3 [8] are also given in the literature.

It is generally believed that the estimated volume is 10^{13} and 20×10^{15} m^3 (standard conditions) of methane gas in onshore and deep offshore areas [9], which is more credible. This number could meet mankind energy needs for almost 1,000 years. Only methane in gas hydrates in the Black Ridge in the southeastern United States can meet energy consumption in the United States (now the consumption level) for 105 years. Current estimates of the carbon content in global fossil-fuel minerals (oil, natural gas and coal) is 5×10^{12}t, yet the carbon content in methane is twice of fossil-fuel minerals, up to 10×10^{12}t [10]. Second, the gas hydrates are a kind of clean energy, which contain high purity methane and less harmful gases. Environmental pollution is in low degree compared with coal, oil, natural gas.

Furthermore, gas hydrates have high energy value. $1m^3$ of gas hydrates is equivalent to $164m^3$ of methane in the normal conditions [11]. Energy density (methane in sediments per unit volume under standard conditions) is 10 times of the other non-conventional energy sources and is 2 to 5 times of conventional natural gas.

2.2. Distributing of Marine Gas Hydrates

For the above reasons, gas hydrates are believed as a new alternative energy of contemporary fossil fuels. It has enormous potential to develop and utilize. And it has been paid great attention by governments, scientific research units, enterprises and other related departments in the developed countries, such as the United States, Germany, Japan, France and Russia.

Geological, geophysical, and geochemical evidence or samples of gas hydrates collected from DSDP (Deep Sea Drilling Project), ODP (Ocean Drilling Program) and IODP (Integrated Ocean Drilling Program). They are reported more than 40 sites which find localities in the oceanic area. However, intact gas hydrates samples have been recovered at only 30 of these localities, and mainly geophysical evidences are BSR (Bottom Simulating Reflectors) and BZ (Blank Zone). Because unambiguous evidences of gas hydrates from cores and drill holes are often lacking, the number of sites where gas hydrates are suggested to occur may be overestimated. Global DSDP–ODP-IODP geochemical data identify many additional deep-water marine sites with large sulfate gradients that lack BSRs, perhaps suggesting the occurrence of previously unrecognized gas hydrate localities. But, about 90% of global oceans have not found any effective evidence. The obvious evidences show the gas hydrates distributing in regular where distribute in the accretion prism of initiative continental margin, the active area of isobathic ocean current in passive continental margin, the mud volcanoes and a few gas-oil seepage area

(Shown in Table 1) .The factors of marine geology, including sedimentary velocity, content of the TOC, granularity of sediment, hydro-dynamic condition and ocean productivity, are illustrated (Shown in Figure 1).

Table 1 Distributing of the marine gas hydrates

Location	Leg/Site	Sediment Type
Hydrate Ridge	ODP204/1244,1249	Clay, Silty clay, clayey silt.
Cascadia Margin	ODP146/888,892;ODP204/1248,1249;IODP311/1326-1329	Silt,Sand-silt-clay
Mexico Margin	DSDP66/490,492	Clay, Silty clay, Volcanic ash
Costa Rica Margin	DSDP84/565;ODP170/1041;ODP205/1253	Nannofossil clay, Volcanic ash, Sand-sized glauconite Pebbles of basalt, Silt,
Guatemala Margin	DSDP67/497,498;DSDP84/568,570;ODP206/1256	Nannofossil clay, Silt,Volcanic ash
Peru Margin	ODP112/ 685,688;ODP201/1228	Pelagic clay;Silty clay
Nankai Trough	ODP131/808;ODP190/1173	Pelagic clay,Volcanic ash
Okushiri Ridge	ODP127/796	Silt，Sand-silt-clay
Blake Ridge	DSDP76/ 533;ODP164/994~ 997;ODP172/1061	Silt，Sand, Pelagic clay
Gulf of Mexico	DSDP618	Silt, Sand-silt-clay
Amazon Fan	ODP 155/935	Silt，Sand-silt-clay
Norwegian Sea	ODP 104/642	Pelagic clay, Silt, Sand
Svalbard Margin	ODP162/986	Pelagic clay, Silt, Sand
Low Congo Basin	ODP175/1077	Clay, Silt, Sand-silt-clay
Milano-Napoli Mud Volcano	ODP160/970,971	Clay, Silt

3. Marine Gas Hydrates: Environmental Effects

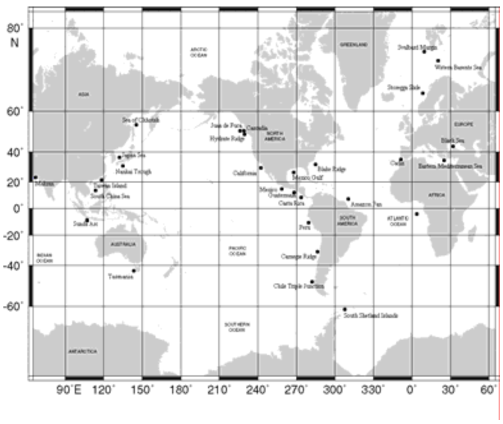
Marine gas hydrates are an important carbon reservoir on lithosphere surface, and a key link in global carbon cycle. But gas hydrates are unstable in nature. Their formation need special conditions of pressure and temperature which is controlled by seawater depth, seafloor temperature and geothermal gradient. The gas hydrate stability zone (GHSZ) are only relativity concept, and they determined by finding the intersection of the local P-T conditions with experimentally determined conditions for three-phase equilibrium among water, hydrate and free gas. Any change in temperature and pressure will cause it to decompose or produce. The decomposition and the release of submarine gas hydrates can lead to decrease the stability of seabed strata, causing submarine landslide. And methane gas overflowed can intensify the greenhouse effect, interaction between which can lead to more serious ecological and environmental disasters.

3.1. Release of Marine Gas Hydrates and Global Warming

Although the volume concentration of methane in the atmosphere is only 1/200 of the concentration of CO_2, methane is an important greenhouse gas, whose global warming potential index (GWP) is 3.7 times of CO_2 by mole number and 20 times of CO_2 by weight. Absorption or release of methane gas hydrates on global climate has a significant impact. Especially the rapid release of methane gas in gas hydrates is likely the culprit to lead to short-scale global climate change. The existing research shows in Paleocene-Eocene global temperature became warm suddenly. It is believed to have occurred suddenly about 55Ma or so (55.6 Ma) and called “Latest Paleocene Thermal Maximum” (LPTM) [12~15]. The temperature in Northern Hemisphere increased 6-12℃during the period of 1Ma. Temperature changed so quickly, which closely related to the changes in global sea level caused by the decomposition and the release of the large number of gas hydrates [16~18].

3.2. Release of Marine Gas Hydrates and Seabed Geological Disasters

Different from the accumulation model of coal, oil, gas and other energy minerals, marine gas hydrates lack of consolidation cap and prone to phase transformation. Regardless of temperature-pressure balance on any changes, the stability zone will be reduced due to the pressure on the surface or temperature increasing, and induced hydrate dissociation. The sensitivity of oceanic gas hydrates and submarine slope stability to the combined forcing of sea level changes and bottom water perturbation is a critical issue for risk assessment in the seabed geological disasters.Methane gas released will break the shackles of gas hydrate stability zone (GHSZ), upward from its weaknesses. And the submarine sediments will move downward under the action of gravity, leading to submarine landslide (Shown in Fig.2). Sea-level changes in the geological history caused undersea landslides continuously. Usually the sediments in the lower continental slope formed a thick layer of several superimposed landslide, such as Cae Fear on continental rise offshore southeastern North America, Beaufort Sea continental slope in the north of Alaska, Amazon deep sea fan, Norwegian continental margin [19~22]. Seismic reflection profiles show that landslide area caused by the decomposition of gas hydrates in the slope of Beaufort Sea in Alaska almost covers the area of occurrence of gas hydrates [23].



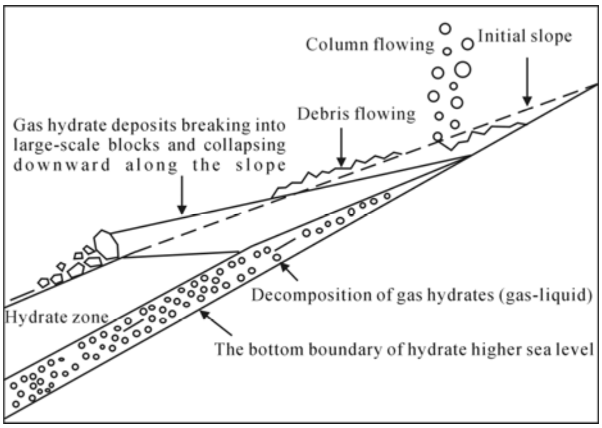


Fig 1. Distribution of marine gas hydrates (after initiall report of DSDP,ODP and IODP)

Fig 2. Seafloor slide caused by marine gas hydrate discompose and release

3.3. The Intrinsic Link of Release of Marine Gas Hydrate and Ecological Disaster

The release of methane in marine gas hydrates can not only cause the greenhouse effect rapidly, but also induce seabed geological disasters. These changes will ultimately affect the biological species on the Earth. The release of gas hydrates caused global warming, which had produced an important role on the evolution of land mammals. Great thermal event appeared in about 55Ma (Paleocene-Eocene). The fundamental reason was that the decomposition of a large number of gas hydrates led to a sudden global warming. Northern Hemisphere temperatures increased 6-12 ℃ in the short term. This change made crocodiles appear in the Arctic Circle [24]. Now the direct relationship between submarine extinction and gas hydrates is concerned very much by scientists. Based on the records of core high-resolution carbon isotope from sites 892 in Ocean Drilling Program (ODP Leg146) and sites 995 (ODP Leg164) [25~27], Dickens believes large quantities release of methane in gas hydrates in the short period was the direct reason that 1/2 to 2/3 of benthic animals became extinct in the turn of the Paleocene and Eocene (about 55Ma) [28].

4. Discussion

Resources and environment are the conditions for human to survive, and they are the basic of sustainable development for society and economy. The development and utilization of new energy sources must be based on the premise of safety development and environment-friendly. Marine gas hydrates show one important role in the global carbon cycle, but they are regarded as energy resources firstly. Gas hydrate may be considered a future energy source not because the global volume of hydrate-bound gas is large, but because some individual gas hydrate accumulations may contain significant and concentrated resources that may be profitably recovered in the future. The decomposition and the release of gas hydrates in large-scale in geological history caused the greenhouse effect and extinction of marine life. These events show, in the process of the development and use of marine gas hydrates, the safety of production technology must be solved at first. Due to the limitations of the occurrence mode and the technical level of marine gas hydrates, at present, the development and utilization of the resources are still tentative. How to use these future energy must consider the only way to protect biodiversity and vulnerable marine ecosystems effectively. And it has great significance for the sustainable development of human.

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References

[1] David R, Olivia W, Sangyong L, et al. Sediment surface effects on methane hydrate formation and dissociation. *Marine Geology* 2003;198:181-190.

[2] Sassen R, MacDonald I, Guinasso N, ed al. Bacterial methane oxidation in sea-floor gas hydrate: Significance to life in extreme environments. *Geology* 1998; 26:851-854.

[3] Sloan D and Koh C. *Clathrate Hydrates of Natural Gases*. 3rd ed. Beijing:Chemical Industries Series;2007.

[4] Lerche I. Estimates of Worldwide Gas Hydrate Resources. *Energy Exploration & Exploitation* 2000; 18: 329-337.

[5] Alexei V. Milkov. Global estimates of hydrate-bound gas in marine sediments: how much is really out there? *Earth-Science Reviews* 2004; 66: 183-197.

[6] Gornitz V. Potential distribution of methane hydrates in the world's oceans. *Global Biogeochemical Cycles* 1994; 8:335-347.

[7] McIver R. Role of Naturally Occurring Gas Hydrates in Sediment Transport. *American Association of Petroleum Geologists* 1982; 66:89-792.

[8] Soloviev A. Global estimation of gas content in submarine gas hydrate accumulations. Proc. VI Int. Conf. on *Gas in Marine Sediments*. St. Petersburg, Russia; 2000, p. 123–125

[9] Grauls D. Gas hydrates: importance and applications in petroleum exploration. *Marine and Petroleum Geology* 2001; 18:519-523.

[10] Yoann C, Philippe A and Christian D.Storage and release of fossil organic carbon related to weathering of sedimentary rocks. *Earth and Planetary Science Letters* 2007;258:345-357.

[11] Kvenvolden K. A review of the geochemistry of methane in natural gas hydrate. *Organic Geochemistry* 1995; 23:997-1008.

[12] John M and Stephen J. Regional uplift, gas hydrate dissociation and the origins of the Paleocene–Eocene Thermal Maximum. *Earth and Planetary Science Letters* 2006; 245:65-80.

[13] Samantha G, Heather S, Paulown B, et al. Ocean acidification and surface water carbonate production across the Paleocene–Eocene thermal maximum. *Earth and Planetary Science Letters* 2010; 295: 583-592.

[14] Kunio K, Kotaro T, Maria P, et al. Anomalous shifts in tropical Pacific planktonic and benthic foraminiferal test size during the Paleocene–Eocene thermal maximum. *Palaeogeography, Palaeoclimatology, Palaeoecology* 2006; 237: 456-464

[15] Higgins J and Daniel P. Beyond methane: Towards a theory for the Paleocene–Eocene Thermal Maximum. *Earth and Planetary Science Letters* 2006; 245: 523-537.

[16] Lerche I and Bagirov E. Guide to gas hydrate stability in various geological settings. *Marine and Petroleum Geology* 1998; 15: 427-437.

[17] Demirbas A. Methane hydrates as potential energy resource: Part1– Importance, resource and recovery facilities. *Energy Conversion and Management* 2010; 51:1547-1561.

[18] Mienert J, Vanneste M, Bünz S, et al. Ocean warming and gas hydrate stability on the mid-Norwegian margin at the Storegga Slide. *Marine and Petroleum Geology* 2005; 22: 233-244.

[19] Hyndman R and Davis E. A mechanism for the formation of methane hydrate and sea floor bottom-simulating reflectors by vertical fluid expulsion: Vertical Fluid Expulsion. J*ournal of Geophysical Research* 1992; 97:7025-7041.

[20] Borowski W, Paull C and Ussler W. Carbon cycling within the upper methanogenic zone of continental rise sediments: An example from the methane-rich sediments overlying the Blake Ridge gas hydrate deposits. *Marine Chemistry*1997; 57: 299-311.

[21] Borowski W. A review of methane and gas hydrates in the dynamic, stratified system of the Blake Ridge region, offshore southeastern North America. *Chemical Geology* 2004; 205:311-346.

[22] Bünz S, Mienert J and Berndt C. Geological controls on the Storegga gas-hydrate system of the mid-Norwegian continental margin. *Earth and Planetary Science Letters* 2003; 209: 291-307

[23] Lopez M. Architecture and depositional pattern of the Quaternary deep-sea fan of the Amazon. *Marine and Petroleum Geology* 2001; 18:479-486.

[24] Judge A and Majorowicz J. Geothermal conditions for gas hydrate stability in the Beaufort-Mackenzie area: the global change aspect. *Palaeogeography, Palaeoclimatology, Palaeoecology* 1992; 98:251-263.

[25] Ananthaswamy A. Crocodiles in the Arctic Is carbon dioxide to blame? What causes climate change? *The New Scientist* 2010; 206:38-41.

[26] Carson B, Kastner M, Bartlett D, et al. Implications of carbon flux from the Cascadia accretionary prism: results from long-term, in situ measurements at ODP Site 892B. *Marine Geology* 2003; 198:159-180.

[27] Egeberg P, Dickens G. Thermodynamic and pore water halogen constraints on gas hydrate distribution at ODP Site 997 (Blake Ridge).*Chemical Geology*1999; 153:53-79.

[28] Dickens G. The potential volume of oceanic methane hydrates with variable external conditions. *Organic Geochemistry* 2001;32:1179-1193.